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### Handedness and birth stress in children and young adults with learning or behavioral difficulties

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**WORC Paper 96.06.006/7**

**J.G.M. Scheirs  
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**J.G.M. Scheirs  
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# **Handedness and birth stress in children and young adults with learning or behavioral difficulties**

J.G.M. Scheirs and F.A.A. van Schijndel

*Keywords: handedness, birth stress, neurodevelopment*

## **Summary**

A literature review by Searleman et al. (1989) suggested that a relationship between the presence of pre- and perinatal complications and handedness does not exist or is very small in normal subjects. Such a relationship might very well be stronger in certain diagnostic groups, however. In the present study, 234 children and young adults with learning and/or behavioral difficulties and with normal intelligence served as subjects to investigate the relationship. Non-right-handers appeared to have suffered more from two specific birth stressors, rhesus antagonism and breathing problems. They also had more problems with spoken language, whereas no relationship was found between handedness and a composite birth stress score. The problems of valid inference making are discussed in terms of statistical power and chance relationships, and it is suggested that stringent interpretations of statistical test results should be avoided in this and other studies. It is concluded that in the diagnostic group of children and young adults investigated here, the effect of pre- and perinatal complications on the development of handedness is either absent or small.

Several theories that have been forwarded to account for the incidence and etiology of left-handedness rely on the effects of pathological factors in neural development.

First, there is the observation by Bakan (1971) that children who are either first born or born to older mothers are more likely to be left-handed. This led Bakan (Bakan et al. 1973, Bakan 1991) to theorize that cerebral anoxia associated with pregnancy and birth complications causes neurological insult, and that left-handedness is a benign symptom or soft sign of this insult.

Satz (Satz 1972, Satz 1973, Satz et al. 1985) elaborated on Bakan's findings by distinguishing between natural and pathological left-handedness. Satz suggested that early damage to the left hemisphere causes some children who are naturally right-handed to switch to their left hand for manual activities, whereas some natural left-handers, by damage to the right hemisphere, make the reverse switch. The latter children then constitute cases of pathological handedness. As it is assumed that there are many more right-handers than left-handers to begin with and that, when damage occurs, both hemispheres are equally likely to be afflicted, the pathological left-handers in a population will outnumber the pathological right-handers. This mechanism explains why there is an excess of left-handers (above the amount of 10 per cent left-handers in the general population) in certain clinical groups that can be suspected to have suffered early brain trauma. Among individuals with mental retardation for instance (Pipe 1990), and among epileptic patients (Harris and Carlson 1988), the incidence of non-right-handedness is about twice that in normal individuals.

In the theory of Geschwind and Galaburda (Geschwind and Galaburda 1985a, Geschwind and Galaburda 1985b, Geschwind and Galaburda 1985c) a disturbed hormone balance in the fetus, i.e. high levels of the male sex-hormone testosterone, is considered to impede left hemisphere development and to cause a compensatory shift to non-right-handedness. The theory of Geschwind and Galaburda in fact extends far beyond this causal explanation and predicts associations between left-handedness and all kinds of talent as well as disease and inability. Among the problems associated with non-right-handedness are developmental learning disorders, disorders of the immune system, physical illnesses and abnormalities, and birth complications (McManus and Bryden 1993). In the view of Geschwind and Galaburda, strong left hemisphere dominance for handedness and language is the standard and thus, as in



Bakan's view, all manifest left-handers can be considered pathological. In the view of Satz, only part of the left-handed population and an even smaller part of the right-handed population is due to pathological development. The remainder consists of individuals who have their handpreference determined by 'natural' causes, that is, by heredity or by influences that act postnatally.

This article studies the relationship between birth complications or birth stress and handpreference. An association between birth complications and left-handedness fits in all of the above views on the role of pathology in development. Whereas in the theory of Bakan pre- and perinatal complications (and the accompanying anoxia) are regarded as the factors causing left-handedness (Bakan 1991), birth complications and left-handedness are both sequelae of a common cause, i.e. hormone imbalance, according to the theory of Geschwind and Galaburda (Geschwind and Galaburda 1985c). The model of Satz (Satz 1972, Satz 1973) explains how minor neurological damage might lead to an increase in manifest left-handedness, while birth stress is simply one of the factors that might have caused such damage.

A review and meta-analysis of the literature on the relationship between birth stress and handedness in samples of normal subjects was carried out by Searleman et al. (1989). Birth order and maternal age were among the variables studied. They found no association between birth order and handedness and only very weak associations (accounting for less than 1 per cent of the variance) between other types of birth stress and handedness. Studies not covered by Searleman et al. (1989), such as those by Van Strien et al. (1987), Levander et al. (1989), Dellatollas et al. (1991), Peters and Perry (1991), and Williams et al. (1992) do not seem to alter the general conclusion: there was no relationship between handedness and birth order or maternal age. An association between handedness and some types of birth stress (such as high blood pressure of the mother, or the need of infant resuscitation after birth) was found by Van Strien et al. (1987), by Williams et al. (1992) and by Levander et al. (1989), but these were all significant associations among larger numbers of nonsignificant ones. Of course it is not surprising that inconsistent results have arisen, given the differences that exist in the definition and assessment of both handedness and birth stress, and in the ways the subjects were selected (see Levander et al. (1989) for a discussion). An even more important factor might have been the small sample sizes in some studies, which lead to low power and to the possibility that connections between birth stress and handedness do exist but cannot be

detected. Despite these considerations, one cannot but conclude that so far the evidence of an effect of birth stress on handedness in normal individuals is very weak.

In their review, Searleman et al. (1989) suggested that the relationship between birth stress and handedness should not only be investigated in normal populations but also in clinical groups. Following the theory of Geschwind and Galaburda, they predicted that the strongest relationship might be found in such groups, for instance in the mentally retarded. This is a reasonable prediction, as the higher incidence of left-handedness in these groups and the higher incidence or severity of pathology during development (supposedly related also to birth stress) make it easier to detect a relationship (Searleman et al., 1989, p. 398). The present article, therefore, studies the relationship between birth stress and handedness in a sample of children and young adults with learning and/or behavioral difficulties. It is anticipated that non-right-handers in this group will show the highest frequency of pre- and perinatal complications.

With regard to one important stressor, low birth weight, Ross et al. (1987) showed that mixed-handers and left-handers were overrepresented among children who had both low birthweight (< 1500 g) and low intelligence (IQs < 85), but not among children who had low birthweight and normal intelligence. Similarly, Saigal et al. (1992) found more non-right-handedness in extremely low-birthweight children (< 1000 g) as compared to children born at term, while the highest incidence of non-right-handedness was present in those low-birthweight children that also showed neurological impairments (i.e. cerebral palsy, hydrocephalus and/or IQ < 70). Harris and Carlson (1988, p. 354) proposed that where birth complications go along with a rise in non-right-handedness, there also must be associated neurological symptoms. Or that where non-right-handedness is a sign of pathology, it is improbable that this will be the only sign. Since Wechsler IQ scores are available for the subjects in this study, the role of intelligence as a possibly important third variable is also investigated.



## **Method**

### *Subjects*

The sample consisted of 234 children and young adults who had undergone neuropsychological examination at the psychology department of Tilburg University, The Netherlands, during the years 1989 - 1993. In addition to the results of several psychological tests, extensive information had been gathered by questionnaire concerning the subjects' former and current health status, the course of pregnancy and birth, and other developmental and social characteristics such as the handedness of the subjects and of their family members. The questionnaires providing this information had been filled in by one of the subjects' parents, in nearly every instance by the mother.

The subjects were selected from a larger sample (N=290) on the basis of the reason for their referral. Only subjects who were referred because of learning and/or behavioral problems, as indicated by their parents, teacher or health care practitioner, were included. Children with a history of severe neurological insult (e.g. brain tumor or coma), and children without complaints or problems for whom mere school advice was sought were omitted from the sample. Table 1 displays some important characteristics of the sample.

**Table 1. Characteristics of the total sample studied (N = 234).**

Age in years	Mean = 10.1 (sd = 3.6) Range 3 - 6: N = 29 Range 7 - 10: N = 107 Range 11 - 14: N = 68 Range 15 - 26: N = 30
Sex	Males: N = 178 (76%) Females: N = 56 (24%)
Type of problem	Learning problems: N = 167 (71%) Behavioral problems: N = 35 (15%) Both: N = 32 (14%)
IQ	WPPSI: mean = 99.6 (sd = 14.1); N = 12 WISC-R: mean = 103 (sd = 14); N = 184 Verbal IQ: mean = 99.3 (sd = 13.9) Performance IQ: mean = 107.2 (sd = 15.4) WAIS: mean = 119.4 (sd = 14.1); N = 16 Unknown: N = 22
Handedness	Right-handed: N = 180 (78%) Non-right-handed: N = 51 (22%) Unknown: N = 3
Handedness mother	Right-handed: N = 185 (85%) Non-right-handed: N = 33 (15%) Unknown: N = 16
Handedness father	Right-handed: N = 176 (84%) Non-right-handed: N = 34 (16%) Unknown: N = 24

### *Procedure*

The parental reports, together with those test results that were available for almost all of the children, provided the data to be analyzed. With regard to parents reporting about pregnancy and birth complications of their children, the question of the reliability of such statements can be raised, since there is low correspondence with hospital records (Schwartz 1988, Schwartz 1990). We are aware of this difficulty and will return to its consequences in terms of valid decision making in the discussion section. Suffice it to say here that many existing studies did nevertheless rely on interviews with the parents or the subjects for data collection (see Levander et al. 1989), and that further, as a partial solution to the reliability problem, we decided to include only those questionnaire items in our study that were unambiguously stated and that produced answers that could easily be quantified.

The variables studied were: sex and age of the subject, age of the mother at birth, birth order (both including and excluding miscarriages), handedness of the subject (right-handed or non-right-handed), birth stress, problems with the pronunciation of words, getting speech lessons, epilepsy, allergical reactions, handedness of father, handedness of mother, number of brothers or sisters being non-right-handed, and presence of non-right-handedness among relatives outside the family (grandparents, uncles, aunts and cousins). The age and birth order variables and the number of non-right-handed siblings and relatives were numerical variables. The other variables were scored positively if the parents indicated that this problem or characteristic was present.

The variable 'birth stress' was a composite score indicating the total number of birth complications and was based on any of the following conditions: (1) Rhesus-antagonism, (2) Illness of the mother during pregnancy (toxemia, diabetes, pyelitis, thyroid disease or rubella), (3) Medication during delivery (excluding medication to induce labor), (4) Narcosis, (5) Prematurity (less than 37 weeks), (6) Low birth weight (less than 2500 g), (7) Breech delivery, (8) Forceps delivery, (9) Vacuum extraction, (10) Caesarian section, (11) Multiple birth, (12) Breathing difficulty, (13) Umbilical cord around neck, (14) Skin of the baby being blue or yellow, (15) Use of incubator, (16) Any other difficulty on the part of the baby during or shortly after birth.



Further, WPPSI, WISC-R or WAIS intelligence scores, depending on the age of the subjects, were available from the neuropsychological test battery for most of the subjects. After an initial screening for possible relationships with handedness (which were in fact not found), the results of several other test scores from this battery were discarded, because the number of observations appeared to be too small. Thus only the IQ scores remained for analysis. These scores were based on the Dutch editions of the Wechsler scales (Stinissen et al. 1970, Berger et al. 1973, Van Haasen 1976).

## Results

Table 1 shows the characteristics of the total sample. It appears that the subjects are mainly boys and that they have normal IQs. A  $t$  - test for dependent observations reveals that for the WISC data the performance IQ is higher than the verbal IQ ( $t_{(182)} = -7.43$ ;  $p = 0.000$ ). With regard to the WPPSI and WAIS test results, for which only few observations are available, the observed differences are in the same direction. The proportion of non-right-handers as inferred from parental report is 0.22. This proportion is higher than the incidence of non-right-handedness among the subjects' mothers and fathers (0.15 and 0.16, respectively), although the differences reach values of the test statistic that are only marginally significant ( $X^2_{(1)} = 3.55$  and  $2.45$ ;  $p = 0.06$  and  $0.12$ , respectively). When the handedness data of the fathers and mothers are combined, however, the chi-square value testing for a higher incidence of non-right-handedness in the subjects equals 4.21, and the associated probability is 0.04.

Table 2 shows the relationships of handedness with the other variables. Chi-square statistics and associated probabilities are also reported. Two-tailed probabilities of Fisher's exact test replace chi-square probabilities in two by two tables where the smallest expected frequency is less than five.

**Table 2. Percentages of right-handers and non-right-handers that belong to the categories listed at the left (total sample). Values within parentheses in the columns labeled "Right-handers" and "Non-right-handers" indicate the sample sizes in these categories. The absence of chi-square values in some of the rows indicates that Fisher exact probabilities have been calculated.**

	Right-handers	Non-right-handers	X <sup>2</sup>	p-value
Sex:			0.77	0.38
male	74.4%	80.4%		
female	25.6%	19.6%		
	(180)	(51)		
Age:			5.85	0.12
3-6	10.6%	19.6%		
7-10	46.1%	47.1%		
11-14	31.7%	17.6%		
15-26	11.7%	15.7%		
	(180)	(51)		
Birth order (miscarriages excluded):			3.59	0.31
1	43.6%	31.3%		
2	36.9%	50.0%		
3	15.4%	18.8%		
>3	4.0%	0.0%		
	(149)	(32)		
Birth order (miscarriages included):			0.90	0.82
1	34.9%	34.0%		
2	38.9%	34.0%		
3	14.9%	20.0%		
>3	11.4%	12.0%		
	(175)	(50)		
Age of mother:			2.06	0.72
19-23	7.3%	12.2%		
24-26	23.6%	18.4%		
27-29	33.7%	32.7%		
30-32	20.8%	18.4%		
33-42	14.6%	18.4%		
	(178)	(49)		
Rh. antagonism	2.1%	9.7%		0.07
	(145)	(31)		
Illnesses mother	6.1%	12.9%		0.24
	(148)	(31)		



	Right-handers	Non-right-handers	X <sup>2</sup>	p-value
Medication	16.3% (166)	20.0% (45)	0.35	0.55
Narcosis	7.1% (168)	10.6% (47)		0.54
Premature	8.6% (174)	2.0% (51)		0.13
Low birth weight	9.2% (173)	3.9% (51)		0.38
Breech birth	5.4% (168)	4.1% (49)		1.00
Forceps delivery	5.1% (177)	7.8% (51)		0.49
Vacuum extraction	5.1% (177)	3.9% (51)		1.00
Caesarian section	5.1% (177)	7.8% (51)		0.49
Multiple birth	0.6% (177)	0% (51)		1.00
Breathing problems	8.8% (159)	20% (45)	4.39	0.04
Umbilical cord around neck	14.5% (166)	13.3% (45)	0.04	0.85
Deviant skin colour	18.0% (161)	25.5% (47)	1.30	0.25
Other complications	12.6% (174)	16.0% (50)	0.38	0.54
Incubator	16.9% (177)	23.5% (51)	1.14	0.29
Birth stress (composite score):			3.52	0.32
0	46.1%	33.3%		
1	23.6%	23.5%		
2	10.1%	15.7%		
>2	20.2% (178)	27.5% (51)		

	Right-handers	Non-right-handers	X <sup>2</sup>	p-value
Problems with pronunciation of words	24.0% (179)	29.4% (51)	0.61	0.43
Stuttering	6.1% (179)	7.8% (51)		0.75
Speech lessons	21.8% (179)	35.3% (51)	3.88	0.05
Epilepsia	4.0% (176)	6.1% (49)		0.46
Allergies	28.0% (164)	31.1% (45)	0.16	0.69
Mother non-right-handed	14.4% (167)	14.6% (48)	0.00	0.97
Father non-right-handed	16.4% (159)	14.6% (48)	0.08	0.77
Siblings non-right-handed:			1.65	0.44
0	81.8%	76.1%		
1	17.0%	23.9%		
2	1.3% (159)	0.0% (46)		
Other relatives non-right-handed:			11.49	0.003
0	54.5%	26.1%		
1	26.3%	43.5%		
>1	19.3% (156)	30.4% (46)		

Table 2 provides no evidence for an association between handedness and either birth order, age of the mother or birth stress (composite score). Significant relationships are found between handedness on the one hand and breathing problems and speech lessons on the other. There is also a marginally significant relationship with rhesus antagonism. These three characteristics occur more often in non-right-handers. Also, non-right-handed subjects have more non-right-handed relatives, but this relationship does not hold with regard to the closest relatives, i.e. parents or siblings.

Both WISC-R and handedness data were available for 182 subjects. Based on these data, there is no difference in intelligence between the handedness groups (Right-handers: mean IQ = 103.4; non-right-handers: mean IQ = 100.7;  $t_{(180)} = 1.00$ ;  $p = 0.32$ ). Similar negative conclusions are reached when the verbal and performance (WISC)-IQs are considered separately ( $t_{(180)} = 0.95$ ;  $p = 0.34$  and  $t_{(179)} = 0.42$ ;  $p = 0.68$ , respectively), and when the WPPSI or WAIS IQs are analyzed. Neither does the relationship between handedness and birth stress become more prominent when intelligence is taken into account as a third variable: an analysis of covariance with handedness as the independent variable, IQ score (either WPPSI, WISC or WAIS) as the covariate and birth stress (composite score) as the dependent variable, reveals no significant effects:  $F_{(1/202)}$  for the handedness factor = 2.22,  $p = 0.14$ ;  $F_{(2/202)}$  for the regression effect = 0.11,  $p = 0.90$ .

## Discussion

In a sample of children and young adults with learning or behavioral difficulties, no evidence was found that birth order or maternal age at birth are related to handedness. This negative result is in line with the review by Searleman et al. (1989), and with other studies that investigated the role of either birth order or maternal age as determinants of handedness in normal subjects (Van Strien et al. 1987, Levander et al. 1989, Dellatollas et al. 1991, Peters and Perry 1991, Williams et al. 1992). Neither did we find an association between handedness and a composite score incorporating several types of birth stress. Non-right-handers, however, showed more signs of a specific birth stressor: breathing problems. Non-right-handers also were more liable to rhesus-antagonism and they had more problems related to spoken language as evidenced by their increased attendance of speech lessons.

For a correct interpretation of the above results, two statistical arguments should be considered. The first is the decreased statistical power of the applied tests under the condition of low correspondence between maternal and medical reports, as pointed to in the Methods section. If one assumes that when parents report about the health status of their children, there is a decrease in the reliability of the dependent variable due to an increase in random error, then a reduction of statistical power must be the result (see Williams and Zimmerman 1989). The power tables provided by Cohen (1988, p. 235 - 236) indicate that the statistical power of our tests with only one degree of freedom and alpha equal to 0.05 can be estimated



to have been about .32 for detecting small effects, and approaching 1 for medium sized effects. Unreliability, however, adds to the loss of power. With a priori power values in the above range, nonsignificant test results cannot be considered confirmations of the null hypothesis. Nonsignificant results indicate one of two things: that the effects were either absent, or that they were small and need higher power (i. e. larger sample sizes) to be detected.

The second argument is the increased overall alpha level that is due to carrying out several tests. With large numbers of tests, the chance of finding at least one significant result, given that no effects exist at all, might well rise above the per comparison alpha level of, say, five percent. The effect of the two above arguments is that some significant results might be spurious ones, and that some of the nonsignificant results might turn into significant ones if power had been larger. Thus, the certainty with which conclusions can be drawn from the data is often not as high as the reported significance levels would suggest. The latter implies a more favourable and, in our opinion, a more realistic position towards studies that rely on retrospective data collection than the one forwarded by Schwartz (1990), who wrote that 'conclusions and theoretical formulations drawn from these results must be treated as no more than speculation at best'. We feel that this type of data, rather than being speculative, have the merit of pointing to potential questions that future research should address and of providing meta-analysts with a balanced account of the strength of effects. In any case, our study is not the only one for which the above precaution holds. Levander et al.'s (1989) study, for instance, showing an association between handedness and rhesus factor problems like ours but negative results for all other variables, can be criticised for having not only many tests but also few subjects. The implication is not only that one should try to achieve high power in individual studies, but also that only the replication of studies can reveal the true state of affairs.

Given the above arguments and the conflicting results concerning the effects of breathing problems and rhesus antagonism on the handedness of normal subjects (see Searleman et al. 1989), it seems wisest not to overinterpret our significant findings. The same holds with regard to an association between non-right-handedness and speech disorders, which was what we found but which has not unequivocally been demonstrated in former studies (Harris & Carlson 1988). What can be concluded is that, if birth stress influences handedness in the

specific diagnostic groups that we studied, the effects are probably small, just as they were in the Searleman et al. (1989) study.

The fact that non-right-handed subjects were reported to have more non-right-handed (distant) relatives, while no such correspondence was present among members of a family, can easily be explained. Following Peters (1990, p. 180), we suggest that right-handedness is taken for granted in our society, whereas non-right-handedness is considered exceptional and provokes interest on the part of the subjects and their parents. Being a non-right-hander or having non-right-handed children might thus induce an attentional bias towards the presence of this phenomenon in others. If this is so, the above relationship must be considered an artifact and our data do not show any evidence of familial sinistrality.

We expected to find an association between non-right-handedness and birth stress because subjects with learning and behavioral difficulties were considered more likely to have suffered from (minor) neurological insult than normal subjects. If there is a higher incidence of pathological development in these subjects, an increased prevalence of non-right-handedness might also be expected. This was indeed the case. The data show that 22 per cent of the subjects, 15 per cent of their mothers and 16 per cent of their fathers were non-right-handed, respectively. As argued above, no relationship appeared to exist between the handedness of the parents and that of their children. If valid, these results together provide arguments for the suggestion that the population of learning and behaviorally disabled subjects studied here contains a certain proportion of pathological left-handers, and that this proportion is higher than in a normal population (Satz et al. 1985). The question that arises then is, whether this pathology can only be inferred from the shift in the distribution of handedness and from the lack of familial sinistrality, or whether it is paralleled by some signs of neurological impairment, as was suggested by Harris and Carlson (1988). Can pathology really be demonstrated in non-right-handers? No indications that either birth stress or intelligence was related to the handedness of individual subjects could be obtained from the present study. In two studies of infants who were prematurely born or had extremely low birth weight, the relationship between handedness and gross abnormalities of the brain as inferred from ultrasound scans was investigated. The presence of unilateral periventricular haemorrhage appeared to be associated with handedness in only one of the studies and disappeared when mixed- and left-handers were combined into one group (Marlow et al.



1989, O'Callaghan et al. 1993). These studies provide only weak evidence that brain insult determines handedness. This is not to say that brain injury cannot influence lateral preferences, as it has been shown in childhood hemiplegia for instance, that eye and ear preferences are related to the side of the paralyzation (Costeff et al. 1988). It is becoming increasingly difficult to see, however, how 'minor' abnormalities can be held responsible for non-right-handedness in a considerable number of cases, whereas gross cerebral abnormalities detected by ultrasound techniques do not seem to show such an effect (Marlow, Roberts, and Cooke 1989). Perhaps an alternative explanation for the increased incidence of non-right-handedness in certain diagnostic groups should also be considered. Such an explanation says that apart from pathology being a potential cause of non-right-handedness in some cases, it could also be the result in others. It might be that non-right-handers are overrepresented in clinical settings and certain diagnostic groups, partly because of a functional incompatibility between the preferred use of the left hand and the demands of everyday life.

We believe that the theorizing on human handedness and on the role of pathology would benefit from the continued research with specific diagnostic groups, as was proposed by Searleman et al. (1989). As it can be argued that the present investigation failed to find the predicted effects of birth stress because of the normal intelligence of the subjects, it might be fruitful to pursue the question with subjects having IQs clearly below normal. Research into handedness and brain function could perhaps gain even more from direct attempts to identify the pathological process, for instance by brain imaging techniques as described above.

## Notes

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